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The Explosion of Commercial Space and the Implications for National Security*

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BECAUSE I SPENT 27 years of my professional life in assignments related to the national-security space program and because space continues to be my abiding passion, it is not surprising that I have chosen to write about space—specifically, the significant changes in the evolution of the national space program and my views on the implications for military space. The article also addresses some ramifications for the intelligence community.

A vitally important topic, space has always played a significant strategic military role, but the mainstream neither understood it nor appreciated its criticality to modern tactical war fighting—until Operation Desert Storm, which opened the eyes of senior military leaders. Now, space is like air-

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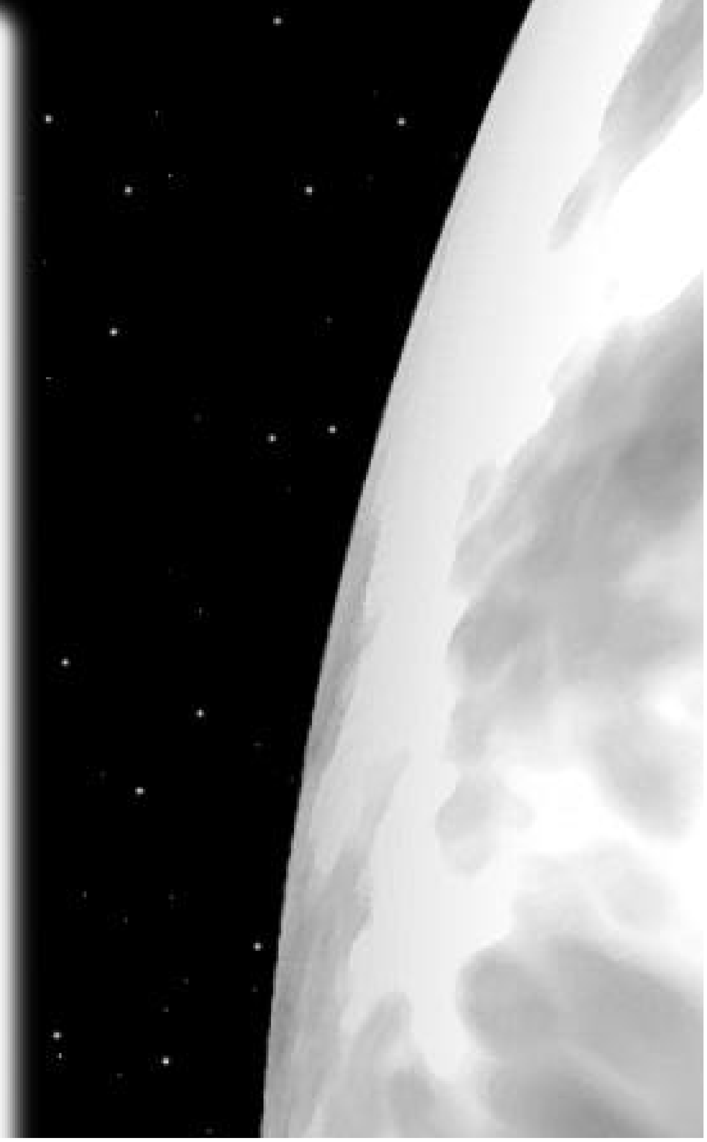
conditioning—everyone who needs and wants information from space wonders how we ever got along without it. All joint documents underscore this fact, including *Joint Vision 2010* and *Transforming Defense: National Security in the 21st Century,* the latter report emphasizing the importance of space and stating that “unrestricted use of space has become a strategic interest of the United States.”[1]

Although other services have been involved in space and certainly employ data from space in all operations, the Air Force is the space service for the Department of Defense (DOD), providing the overwhelming majority of both the military space budget and the people engaged in space acquisition and operations. Over the last 15 years, the importance of space within the Air Force has increased substantially. However, the airplane culture has been clearly dominant. Today, for a variety of reasons—Desert Storm, loss of overseas information-gathering assets, the growing military dependency on space, technology that permits the placing of more capabilities in space, and the steadily diminishing DOD budget—the Air Force has totally and unequivocally embraced the space mission and has made a commitment to its steward-



ship. Nowhere is this commitment better enunciated than in the strategic-vision document *Global Engagement: A Vision for the 21st Century Air Force*: "We are now transitioning from an *air* force into an *air and space* force on an evolutionary path to a *space and air* force" (emphasis in original).[2] This document also envisions the integration of air and space, operationally and institutionally. It is interesting to note that Air Force thinking on this vision has evolved in recent months to the point that senior officials now talk about a seamless aerospace rather than a space and air force.

Making this vision a reality will be one of the Air Force's biggest challenges in the next century. Besides melding the air and space cultures, which will take years to achieve, the service also faces the challenge of evolving the necessary technology in the face of continued budget pressure. Military space programs have fared well in this decade—the topline budget has generally remained constant while most of the other major mission areas have declined. The military space budget today is around $7 billion, 85 percent of which is in the Air Force.[3] This budget sustains and modernizes the communications, navigation, warning, weather, space command and control, and launch capabilities on which we all depend. In the absence of a major change in the threat or the geopolitical equation, the next century likely will continue to see significant pressure on the defense budget. To realize the evolutionary vision of the Air Force, however, will probably entail performing new missions from space. Given the continued budget constraints, the Air Force will have an increasingly difficult time funding the sustainment of current military-space force structure while at the same time pursuing new opportunities critical to realizing our vision.

This article suggests a greater reliance on commercial space as an approach to this dilemma. On the one hand, commercialization is not a total panacea. To be sure, some functions are not amenable to commercialization, such as missile warning, signals intelligence, certain surveillance functions integrated into weapon systems, heroically survivable assured communications, and space weapons. On the other hand, the commercial space industry is expanding at such a rate and with such marvelous capabilities that it seems reasonable if not inevitable that a number of missions—heretofore the exclusive province of the government—can be satisfied or augmented commercially. We can also realize significant efficiencies by taking advantage of commercial space.

Evolution of the National Space Sectors

The Soviets' launch of *Sputnik I* created a crisis of US national identity that galvanized both government and industry. One of President Dwight Eisenhower's initiatives to deal with this crisis was the National Aeronautics and Space Act of 1958, which created the National Aeronautics and Space Administration (NASA) and established the policy that devoted the civil space program to "peaceful purposes for the benefit of all mankind." At the same time, the act clearly stated that "activities peculiar to or primarily associated with the development of weapon systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of the Department of Defense."[4] In other words, the act explicitly established—in law and in policy—a separate and independent military space program.

At about this same time, the Eisenhower administration had grave concerns that the Soviets enjoyed a large lead over the United States in the development of long-range missiles—the beginning of the so-called missile gap. To obtain hard intelligence on Soviet missile development, a joint Central Intelligence Agency (CIA)–Air Force team developed the U-2 aircraft, which began flying over the USSR in June 1956. Because of the vulnerability of these aircraft, the CIA and Air Force began the development of reconnaissance satellites,

combining these separate efforts with the creation of the National Reconnaissance Office (NRO) in September 1961.[5] This covert office—whose existence remained unknown until 1992—conducted its operations in the utmost secrecy.

Thus, three space sectors—civil, military, and intelligence—have existed since 1961. Although the sectors interacted in areas such as selected technology transfer, launch, and satellite command and control, they remained independent for 30 years, for the most part due to distinct differences in their missions.

The fourth sector—commercial—also began in the early 1960s with the launch of the first communications satellite. From the outset, space communications proved an attractive venture and, over time, grew not only in the United States but also in Canada, Great Britain, France, and several international consortia, all of whom built commercial communications satellites. Although the other sectors had their origins in law and presidential policy, not until the Reagan administration did we identify commercial space as a separate sector with comprehensive policy underpinnings.[6] Growth of the communications-satellite market; industry expansion; and emerging commercial markets for launch, navigation, and remote sensing led to this formal recognition. Moreover, this emerging industry also faced foreign competition— either from international consortia or from strong aerospace countries such as France. Because the Reagan administration was clearly probusiness, it believed that commercial space needed a solid public-policy foundation.

This bit of space history provides a historical context for the components of our national space program. In sum, we established our four space sectors as independent entities. Each president since Eisenhower enunciated his administration's space policy, which reaffirmed the separateness of the sectors. In the last 15 years, the sectors gradually have become more interdependent. Today, for example, NASA, the NRO, and the Air Force are entering into cooperative partnerships—including joint architectures, technology sharing, and joint programs—at an unprecedented rate. All sectors will continue to converge and overlap—an interdependence that is not only inexorable but also good government.

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To use a solar-system analogy, one may describe space sectors as planets in their own orbits, which, over time, have begun to converge. In the twenty-first century, the planet/sector with the highest density—and thus gravitational pull—may well be the commercial sphere. In other words, although we will always have a compelling need for strong military, intelligence, and civil space sectors, some traditional missions will likely break off and be absorbed by the commercial sector.

The Explosion of Commercial Space

For nearly 40 years, the government has dominated the space business. Low-risk, cost-plus contracts with NASA, the military, or the intelligence community were the norm. Today, that picture is changing, and the rate of change will become even more dramatic. A number of factors have contributed to this phenomenon: the rapid evolution of information technologies, such as the explosive growth in semiconductor technology and the extraordinary advances in digital signal processing and voice compression; progress in international space policy, including the increasing deregulation of telecommunications services, the allocation of new spectrums to

Discovery is launched on the first all-military shuttle mission on 24 January 1985. "Although the government used to have a virtual monopoly on the systems and sites to access space, that picture has fundamentally changed."

commercial satellite communications, and the allowance of higher imagery resolution for commercial remote sensing; fundamental changes in the process and cost of satellite manufacturing; the increased reliability (if not decreasing costs) of launches; and an expanding global demand for satellite services driven by the information revolution.

Consequently, a remarkable infusion of private capital into space and space-related industry has occurred. According to estimates by Space Publications and the consulting firm A. T. Kearney, worldwide revenues from space are currently $88 billion annually, projected to grow to $117 billion by 2001.[7] Although this growth may not be surprising, the fact that the government is not the engine may indeed be surprising. The commercial space market is the driver—its growth is 20 percent annually compared to about 2 percent for the government. Incidentally, in 1996 the total revenues of the commercial sector surpassed the government's for the first time (53 percent and 47 percent, respectively).[8] By 2001 commercial revenues may account for 70 percent of space-industry revenues.

Furthermore, if one examines and aggregates all the various satellite ventures planned over the next 10 years, the number of satellites projected for launch into orbit totals over seventeen hundred.[9] Although all such ventures may not prove successful, the launch of more than one thousand satellites would probably be a conservative estimate. This demand is fueling a commensurate launch requirement that as late as four years ago was considered wildly speculative and highly improbable. I can make that statement with some certainty because five years ago I was deeply engrossed in chairing a national space-launch study. We thought we were pretty bullish, but our predicted launch manifests were well off the mark. One finds a certain wisdom in Yogi Berra's maxim that it is tough to make predictions, particularly about the future. Although several entrepreneurs had plans to launch tens of small communications satellites to low Earth orbit (LEO), funding was problematical, and no one at that time anticipated the extent of this market. Today, these proliferated systems have become a reality and are now being launched. These new multisatellite communications constellations will clearly dominate future launch manifests.

Communications

As it was in the past, space-based communications is the giant in space commerce. The giant clearly will be even more dominant in the future, and the information revolution will be the driver. Globally, governments, business, and individuals want to receive more data faster, which will drive the demand for bandwidth. Satellites offer an efficient and rela-

tively inexpensive means to move large amounts of data quickly.

Quite a bit of excitement and attendant publicity has characterized these new satellite-communications ventures. Part of the excitement derives from the players and substantial investment involved. *Business Week* noted that "some of the most dynamic entrepreneurs of recent times are hooked on the great space race and orbiting egos will enhance a drama already fueled by mind boggling sums."[10] The names of the players make anyone sit up and take notice: Bill Gates, Rupert Murdock, Craig McCaw, and Bernard Schwartz. The projected investment in a host of communications-satellite programs, which account for the bulk of the one-thousand-plus satellites projected for launch, totals about $40 billion.

Although the new distributed systems designed to operate at LEO and medium Earth orbit (MEO) have received most of the attention, traditional geosynchronous satellites will continue to play a major role commercially and in support of national security objectives. The Commercial Space Transportation Advisory Committee of the Department of Transportation predicts an average of 33 launches annually to geosynchronous orbit over the next decade.[11] Although many people in the space community are converting to the "smaller is better" mantra, satellites for this orbit will continue to become heavier and more capable. Factors influencing the demand for heavier satellites include the availability, in the not too distant future, of new heavy-lift launch vehicles, the increased cost-effectiveness of larger spacecraft (on a dollars-per-transponder basis), a trend to larger antennae, increasing power requirements to accommodate the expanded capability, and orbital congestion. In other words, because the geosynchronous belt is becoming crowded, the slots are becoming dearer; consequently, space businessmen want to field the most capable satellite. That means heavier satellites with as many transponders as possible. The desirability of maximizing transponders per satellite is an inexorable trend. Twenty years ago the average communications satellite had 10 transponders; today the figure is 30.[12]

Several new geosynchronous programs under development, such as Cyberstar, Spaceway, Astrolink, and Euro sky Way, are designed to provide global, two-way, broadband capability to meet the needs for voice, data, interactive multimedia, and video teleconferencing. These new programs will also address the need to service the demands of the Internet—a market that may well surpass phone services or broadcasting. The computer industry must find faster and more efficient ways of moving huge amounts of digital information and video. Incidentally, our national security establishment obviously has the same requirement. Fiber will be important, but I believe that satellites will service that demand before fiber becomes dominant. Geosynchronous satellites likely will always have a major role, given their unique advantages in simultaneous access to large regions and their tremendous capacity.

At a lower altitude regime (MEO and LEO), a number of exciting and technically challenging programs on the horizon will also service the worldwide, two-way, broadband multimedia need. These programs feature very large constellations and have recently received a great deal of notoriety due to the amount of investment involved. In this category the most audacious is probably Teledesic, the so-called Internet in the sky, which envisions 288 satellites in orbits from 100 to 1,400 km. This category also includes the Wideband Euro Sat Telecom (10 satellites), Skybridge (64 satellites), and Orblink (seven satellites).

In another class of low-orbiting communications satellites, the new product is inexpensive, worldwide personal-communications service. The competition here is fierce, and the stakes are high. One may group these programs by the size of the constellation (Big and Little) and by ownership (US-only and primarily foreign). US-owned Big LEOs include Iridium, Globalstar, Ecco, and Ellipso, while mostly foreign-owned Big LEOs include ICO Global (a 79-nation consortium), Signal (a

Russian firm), Euro-African Sat Telecom (Matra-Marconi), and Eco 8 (Telebras-Brazil). US-owned Little LEOs, which provide global, handheld, one-way-store and forward-communications systems, include Orbcomm, Gemnet, FaiSat, and Starsys. Foreign-owned Little LEO programs include Elekon (Russia/Germany), Gonets-D (Russia), Iris (Belgium), and Leo One (Mexico).[13]

These systems, of course, will have tremendous business advantages by linking international corporate offices. In the long run, however, the biggest beneficiaries are likely to be the two billion or so people who live in areas not serviced by phone lines. The risks in this business are very high. Many of the technologies needed for global telephone services are unproven, and overcoming the regulatory obstacles to gain access to foreign markets is by no means certain. Although Iridium has successfully deployed a full constellation of spacecraft, other systems have encountered problems. In September 1998, for example, 12 Globalstar satellites were lost when their Ukrainian Zenit booster failed to reach orbit.

What are the implications of this burgeoning commercial communications-satellite industry for the other space sectors? Operationally, military satellite communications will benefit in terms of access to additional capacity (tremendous increases in available bandwidth and flexibility, as well as multiplicity of alternative communication paths). Today in Bosnia the military is leasing a commercial high-bandwidth, direct-broadcast system to service the needs of US ground forces in Bosnia and their supporting infrastructure in Europe and back in the United States. Currently this system provides reconnaissance data, weather, intelligence on demand, and even Cable News Network to about 30 different locations at 24 megabits a second. In addition to the increases in capacity, commercial communications satellites—because of their relatively short-acquisition time lines—can serve as "gap fillers" to provide continuity of high-bandwidth service in the event of the degradation or loss of government capability.

These new commercial systems also offer efficiencies that potentially have more significance than the operational advantages. The short cycle-times of commercial satellites are remarkable compared to the government-acquisition cycles. For example, new commercial geosynchronous satellites are available 18 months after order—soon to be down to 12 months. For the small LEO systems, time from order to delivery is about three years—probably less as these systems mature. In contrast, the acquisition of national security systems runs 10 to 15 years. To understand the profound contrast in time lines, one should consider that the same plant will build three hundred Teledesic satellites in three years and 15 Global Positioning System (GPS) satellites in seven years.

Because time is money, satellites will be considerably cheaper. Moreover, these short time lines afford the opportunity to take advantage of new technologies because the launch rate is so much faster. How about satellite design? I anticipate a greater use of commercial common buses with tailored national security payloads. This approach would benefit not only from shorter acquisition cycles but also from economies of scale since the commercial vendor produces satellites in numbers far exceeding national security requirements. Finally, taking advantage of commercial production can mean a stable and flexible source of capital. Today, Wall Street is waiting to see how its investments in Iridium, Globalstar, and Orbcomm will pan out. If these ventures meet investors' expectations, this promises to be a capital-rich business with a constancy and continuity of purpose based upon continuing demand. I am not sure that we can anticipate the same stability in government funding.

Launch

The space-launch business is changing as dramatically as space communications. From 1975 to 1995, the national launch rate was about 23 launches a year, with government sectors constituting about 75 to 80 percent of

all launches. Over the next 10 years, the number of launches will increase to 45–52 a year, and commercial launches will exceed both civil (NASA) and those categorized as national security (military and intelligence).[14]

Space launch is also undergoing major modernization. The government's current space-launch systems derive from early intercontinental ballistic missiles (ICBM). Deltas, Atlases, and Titans were effective launch vehicles in the first 15 years of the space age, but as the launch rate declined, the cost of access to space grew considerably. This was especially true of the heavy-lift capability—the Titan's cost had grown to $250–300 million per launch by the early 1990s. Many people were also concerned that the time to launch was excessive, especially for the Titan—from either a military-operational or commercial-competitiveness standpoint. By the early 1990s, due in large part to these high costs and scheduling difficulties, the French Ariane vehicles had captured 60 percent of the commercial market.

Consequently, the 1980s saw a number of programs proposed to make the fleet of expendable launch vehicles (ELV) more efficient and effective. Unfortunately, the military, intelligence, and civil space sectors couldn't agree on a single national program. After about 10 years of debate, an agreement codified as the National Space Transportation Policy emerged in August of 1994. This policy assigned DOD the responsibility for funding and operating the US fleet of ELVs, and NASA became the lead agency for the technology development and demonstration of the next generation of reusable launch vehicles (RLV).[15]

Today, the Air Force has the evolved expendable launch vehicle (EELV), a $2 billion program that recently entered the engineering and manufacturing development phase. This program seeks to leverage private investment to increase the capability of two industry teams over the next two decades. The goals are to increase operational responsiveness and to reduce the launch life-cycle cost by 25 percent. I have no doubt that the program will

A Delta II model 7925 launches NAVSTAR II-10 on 26 November 1990. The expanding GPS constellation provided critical support during Operation Desert Storm.

meet these goals and probably surpass them. Obviously, this lower cost would give the United States a cost advantage and a likely increase in international market share. The first flight for the medium commercial EELV is 2001, and the first government operational payloads are slated for launch in fiscal year 2002. The Air Force has acquired commercial launch ser-vices for a total of 28 government payloads scheduled through 2006.[16]

As for NASA, it is sponsoring RLV technologies such as the X-33 (a one-half-scale single-stage-to-orbit technology demonstrator) and the X-34 small-booster technology demonstrator. Clearly, the military believes that, ultimately, the most effective and efficient way of achieving low-cost, highly operational access to space lies in the RLV or a space plane. Because of profound technical challenges in propulsion, materials, and structures, the military is an active partici-

pant in NASA's RLV technology work. If the RLV demonstrations prove successful, the finished model might be designed to replace the shuttle. Some people believe that financing and operating the new RLV would be a commercial venture.

But the government's launch-modernization efforts tell only part of the story. Although the government used to have a virtual monopoly on the systems and sites to access space, that picture has fundamentally changed. Ariane arose as a competitor in the last decade, and now we have the Pegasus aircraft-launched system, several new commercial ELVs, and a sea-launch option from an oil-rig type of platform south of Hawaii, projected for operation in 1999. Additionally, US firms have entered into agreements with international partners. Russian vehicles such as the Proton, Zenit, Tsyklon, and Kosmos are now available, and the Chinese Long March is also an inexpensive, albeit risky, option. Additionally, we are seeing the emergence of federally endorsed, state-sponsored spaceports. Currently, Florida, California, and Virginia have established programs offering launch services from existing pads at Cape Canaveral Air Force Station, Vandenberg Air Force Base, and Wallops Island, respectively. Other states such as Hawaii and Alaska have strong support for indigenous launch capabilities.

Another very interesting development is the contracting out of launch services. NASA, which has led the way in this area, hired the United Space Alliance, a private joint venture, in 1996 to take over shuttle operations at the Kennedy Space Center. This transition to private management, to be complete in 2002, is designed to get NASA out of the business of running the expensive and manpower-intensive shuttle operation so that it can plow back the savings into its core mission of space sciences and technology.[17]

In sum, space launch is undergoing dramatic change. Highly competitive today, the business will become even more so in the future. Commercial satellite builders—understandably concerned with cost and responsiveness/timeliness—now have a range of options, including the use of multiple launch sites and multiple vehicles for a single satellite constellation. For example, Iridium is being deployed by at least three different launch vehicles (Delta, Proton, and Long March) from three different locations (Vandenberg, Baikonur [Russia], and Taiyuan Space Launch Center [China]).

Given these basic changes, what are the implications for the Air Force and the national security community? First, I think the competition is such that launch costs for the government will drop significantly. I also believe that the continued commercialization of launch is inexorable. Consequently, I think that the Air Force will follow NASA's lead and ultimately purchase launch as a commodity. In the not-too-distant future, I envision commercial firms operating the launch sites at Vandenberg and Cape Canaveral. The Air Force and other satellite builders would contract for a satellite capability on orbit. (The Navy has used this effectively with the ultrahigh-frequency follow-on program.) This outsourcing would prove more cost-effective since it would allow either reduction or transfer of expensive Air Force people to other endeavors.

Remote Sensing

Commercial remote sensing from space is another industry poised to take off during the next decade. Like space launch, this area remained the sole domain of the government for many years. Space reconnaissance systems built and operated by the NRO have provided intelligence on potential adversaries that has proven essential to our military and vital to successful arms control agreements. On the civil side, since 1972 this country has flown Landsat, a civil remote-sensing satellite initially built and operated by NASA and then transferred to the National Oceanographic and Atmospheric Administration. In 1985 the government privatized the program and placed responsibility for it in the hands of the Earth Observation Satellite (EOSAT) Company

under the premise that within a reasonable amount of time, revenues from product sales and ground-station fees would exceed costs. For a variety of reasons—government restrictions on the quality of data, distribution problems, and lack of funding assurance—this commercialization experience failed.

The issue of government policy concerning remote sensing was one of the hottest space issues of the early 1990s. Having participated in the debates, I believe that several reasons existed for redressing remote-sensing policy at that time. The first involved a growing acceptance of the value of Landsat and the French SPOT system for military applications, both of which had proved their worth in Desert Storm. The second entailed a strong belief that the United States needed government support for continued investment in remote sensing to monitor environmental change. Last, and most important, SPOT provided considerably better resolution than Landsat. For that reason there existed legitimate concerns that, without a policy change which removed resolution restrictions, the United States would lose out in the marketplace for multispectral satellite imagery, especially since the French continued to invest in a higher-resolution SPOT system as well as the Helios military reconnaissance system. Other countries staked claims to the market as well, including India, Japan, and the European Union consortium. Two camps emerged, one consisting of industry, environmentalists, and elements of the scientific community who believed that our restrictive policies were unrealistic and wanted a policy to stimulate the remote-sensing business. The other included elements of the military and intelligence communities concerned about unrestricted trade in remote sensing. This group advocated controls over distribution.

The debate resulted in a reasonable compromise—the Land Remote Sensing Act of 1992, which formed the foundation for commercial operation of remote-sensing systems. The act permits companies to apply to the Department of Commerce for licenses to build and operate these systems. Recognizing the security concerns of totally unfettered operation and distribution of data, the act and subsequent policy directives require companies to maintain tasking records so that the government can determine who is asking for what data when. Companies must also maintain control of the spacecraft at all times and be able to limit collection or distribution upon direction of the US government. The act also authorizes the government to cut off or restrict data during times of crisis or conflict.[18]

This act also spoke to the sale of remote satellite systems; specifically, the Clinton administration noted that "such sensitive technology shall be made available . . . only on the basis of a government to government agreement." Further, the act codified the management agreement whereby DOD would build the follow-on Landsat spacecraft and instruments, while NASA would fund and operate the ground station, processing, and distribution systems.[19]

With the proper policy foundation established, the government has granted a total of 12 licenses to date, including five high-resolution electro-optical systems and one high-resolution radar system. Three US ventures appear at this time to be serious competitors in the remote-sensing business. One should note that the volatile, competitive nature of this business will probably produce a shakeout over the next few years.

If first-to-orbit is the measure, then the leader is EarthWatch, Inc. On 24 December 1997, it orbited *EarlyBird 1*, a satellite designed to provide three-meter resolution two to three days from the time of request. As further evidence of the internationalization of space commerce, *EarlyBird 1* was launched on a converted Russian ICBM from the Svobodny Cosmodrome, Russia's newest commercial launch site. Unfortunately, the satellite failed soon after launch. EarthWatch is now focusing on Quickbird, a one-meter resolution system to be launched from Russia on a Kosmos booster.

Another competitor in the game, Space Imaging EOSAT, will initially offer a one-meter

product—the highest resolution of any commercially available system—that will have imagery available within one day of order. The

Worldwide commerce in high-resolution imagery has significant positive and some negative implications.

first Space Imaging satellite was scheduled to launch in late 1998 from Vandenberg Air Force Base atop an Athena-2 booster but has been postponed until the Spring of 1999.

Orbiting Image (ORBIMAGE), the third major player, offers the OrbView series of satellites: *OrbView 1*, a small lightning-and-atmospheric mapper launched in 1995; *OrbView 2*, an ocean-color-and-vegetation mapping satellite launched successfully in August 1997 after a four-year delay; and *OrbView 3*, the company's first venture into the realm of higher resolution, which, after launch in 1999, will provide one-meter resolution (black and white) and multispectral (color) pictures at four meters. A follow-on satellite, *OrbView 4*, will also include an Air Force–sponsored hyperspectral imaging capability (Warfighter 1), advertised as able to detect objects through camouflage and tree canopies. Interestingly enough, ORBIMAGE is the first commercial venture to secure a prelaunch contract with the US government. Planned for launch aboard a Pegasus rocket, *OrbView 4*'s promised features may exceed Pegasus's capability and thus require a Taurus rocket.[20]

Other remote-sensing systems planned for launch in the next few years deserve mention. These include AVSAT, which will provide a more macro view at one-kilometer resolution for geophysical exploitation; Boeing's Resource 21, aimed at the agricultural market; and RDL's Radar 1, which will provide all-weather, medium-resolution radar imagery to commercial buyers. International systems, some flying today and others scheduled for orbit in two to three years, include SPOT (France), RADARSAT (Canada), IRS (India), ALOS (Japan), CBERS (China/Brazil), and EROS (Israel). I believe that these programs will remain viable, primarily because of the market but also because they represent a national resource for their countries.

Clearly, great optimism exists for this particular niche of the commercial space business. Is it justified? Market Plan Graphics, a market-research firm hired by the Department of Commerce, estimates that this will be a $2.65-billion-a-year business by the turn of the century.[21] Others say that this figure is conservative and that anticipated revenue by 2000 is closer to $5 billion. I don't know what is right, but I do know that the Landsat example—involving the government as the primary customer for a relatively low-resolution product—is not the model. Today, all firms offer high resolution, and the number of systems projected for orbit will ensure that the product remains timely. In terms of demand, the uses for remote-sensing data abound—environmental monitoring, energy (oil and gas) exploration, resource management (agricultural and mineral), mapmaking, and community and urban planning, to name just a few. Today, aircraft systems provide synoptic imagery for these and other applications, but high-resolution satellites are far more efficient.

The market is in its infancy but has huge potential. Remote sensing will become an essential part of the information revolution. Images on demand, including three-dimensional products linked to the databases of other geographic information systems and mensurated and indexed through GPS, will become the order of the day. The only question is not whether this will happen but when. I am inclined to believe that the pacing factor will be distribution systems, with their efficiency driven by communications bandwidth and computing power. Although I certainly can't predict the rate of growth, I am inclined to see the util-

ity of remote sensing in the context of the movie *Field of Dreams*—build the systems, and they will come. However, some question may remain as to when the remote-sensing industry will become profitable.

Worldwide commerce in high-resolution imagery has significant positive and some negative implications. On the negative side, how does the military deal with adversaries who can access up-to-date imagery benchmarked against GPS on their personal computers through the Internet? Not only will ensuring the element of surprise in military operations be infinitely more difficult, the imagery becomes the targeting database for the rogue nation or terrorist. This is why the Clinton administration has insisted on "shutter control." I don't have a good answer for this dilemma, but the military of the next century must plan its operations with this potential transparency in mind, and it must develop sophisticated countermeasures. On the positive side, this readily available imagery has immense benefits to our military. One of the intelligence shortcomings of Desert Storm was that the tasking cycle—the time from making the initial request to receiving the imagery product—was too lengthy. Commercial remote-sensing data integrated into a responsive distribution system will meet many needs of the war fighter.

Even today, we see a microcosm of how this might evolve. In a growing number of locations, the Air Force has deployed small, portable ground stations to receive SPOT imagery at tactical field units. That is an Air Force example. A number of other service examples exist, such as trafficability analysis for ground forces and oceanographic and coastal analysis for naval forces. Another very important defense application involves providing the basic source for mapmaking. Generally, we have up-to-date maps of the major countries of Europe and Asia. However, our forces are increasingly being deployed to underdeveloped areas, such as the African states, without current charts.

A most significant area involves the effect of this industry on the amount of money that the military and intelligence communities will need for manned and unmanned airborne-reconnaissance systems and satellite-reconnaissance programs. Currently, we don't have the modeling systems to accurately predict the extent to which commercial imagery can offset or contribute to the satisfaction of government requirements, but those analytical tools are in the works. My sense is that these new commercial capabilities will both complement and reduce the numbers of military and intelligence systems required. The resulting savings could be substantial.

Navigation

The evolution of the commercial aspects of space navigation is not as clear as the areas previously discussed. Although this system was developed for military use and initial commercial sales were to small aircraft, pleasure boats, and large aircraft (after Federal Aviation Administration approval), the market today and in the future will lie overwhelmingly in the consumer sector. To be sure, this is a growing area for commerce—GPS worldwide sales have grown from about $500 million in 1993 to $4 billion in 1998 and are projected to increase to $16 billion by 2003.[22] Navigation systems for cars are the highest growth area, followed closely by handheld systems now available for under $100. The military, of course, has reaped the advantage of the dramatic drop in receiver costs due to commercial volume—aircraft receiver costs have been reduced an order of magnitude. Moreover, GPS receivers have become considerably smaller in weight and volume as well as more reliable.[23] Reduction in cost and size will certainly increase military applications.

Whereas commercial firms will develop and operate either the spaceborne portion of communications, launch, and remote sensing or the associated ground infrastructure, it is unlikely that GPS, the US space-navigation

system, will evolve similarly—at least in the near future. The reason, of course, is the presidential GPS policy of March 1996, which clearly enunciated that "GPS has been de-

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signed as a dual use system with the primary purpose of enhancing the effectiveness of US and allied military forces."[24] As such, the policy reaffirmed DOD's responsibility to acquire, operate, and maintain GPS. At the same time, the US government is committed to the nonmilitary use of GPS on a continuous, worldwide basis, free of direct-user fees. Although the United States wants to prevent enemy use of GPS during wartime, policy dictates that the Air Force must operate GPS as a "global information utility" without unduly disrupting or degrading civilian uses of the system. A recent bilateral cooperation agreement with Japan, the world's other leading producer of commercial GPS equipment, reinforced this commitment.[25]

Although one could envision a GPS antenna as a payload on a commercially provided common bus, the fact that basic GPS will continue to be a government-provided free good for the next several years makes it difficult to envision how a commercial firm would have any incentive to compete. I understand, however, that a few entrepreneurs are looking at providing differential GPS services from space—but the market is not developed. Clearly, precise spatial reference is essential for all forms of robotics, from playing fields to laying pipes. Internationally, I understand that the Germans at one time were thinking about acquiring the Russian GLONASS for a regional augmentation system.

Despite the fact that GPS may not fit the other models, it has obviously become absolutely critical to our armed forces. Virtually all platforms (terrestrial, air, and seaborne), individual ground units, and a host of munitions (missiles and bombs) either now or in the near future will employ GPS for timely and precise navigation. With this dependency has come a real concern about the vulnerability of GPS. President Clinton's policy recognized this vexing problem and directed DOD to prevent the hostile use of GPS to ensure that the United States maintains a military advantage. Thus, GPS has within its design a capability to degrade the accuracy of the signal to one hundred meters—known as selected availability.

As the commercial use of the GPS signal even today dwarfs the military's, with the gap ever widening, the selected-availability feature—controlled by the military—has become a paramount issue over the past few years. Consequently, the policy includes a provision that, beginning in 2000, the president will make an annual determination on the continued use of this feature.[26] The policy provides for discontinuing selected availability within a decade (by 2006), but many people in the national security community believe that it will be discontinued earlier. The Air Force has an effort to deal with these three interrelated problems of denying enemy exploitation, maintaining the capability for US military and allied use, and assuring continued civil use. The Air Force and the Defense Advanced Research Projects Agency (DARPA) are exploring many different technical approaches, including a higher-power signal on the follow-on GPS Block IIF buy; embedding an atomic clock in the receivers; installing adaptive nulling antennae in the skin of the platform or weapon; or reusing the GPS spectrum to provide more capable, jam-resistant signal structure for operations in high-threat environments.

New Military Space Needs

At the outset of this article, I posed the dilemma that the Air Force, DOD's space service, would have great difficulty funding the new space requirements inherent in realizing its strategic vision. The problem lies in affording new initiatives while maintaining basic space services in the face of a flat or declining DOD budget. These reductions could be due to higher-than-anticipated inflation or, in the absence of a pressing threat, the need for DOD to contribute more heavily to the move to balance the budget.

Clearly, we should pursue a number of new military space initiatives over the next 10–20 years. For example, as more commerce is placed in orbit and as we depend more on space, DOD will need a more comprehensive program to protect our assets. The previously mentioned report by the National Defense Panel, *Transforming Defense: National Security in the 21st Century*, recommended increased attention to this area. A comprehensive protection program would include improving our ability to detect and assess threats (surveillance), enhancing the survivability of ground stations and platforms, and using commercial assets to augment national security capabilities, to name a few.[27]

Many people in the Air Force believe that certain surveillance functions now done by aircraft systems such as the E-3 Sentry airborne warning and control system and E-8C joint surveillance, target attack radar system should more appropriately be done from space. Both of these systems use very old airframes and are quite expensive to operate. For years, we have pursued the holy grail of space-based radar (SBR), only to be thwarted by the power-aperture-product problem. To get the quality required for tracking, the spacecraft must be at a relatively low altitude, and to get the global coverage, one must orbit a great many spacecraft. This conundrum led to an expensive program. New technologies in miniaturization, power, and antenna design may permit an affordable SBR (the new term is *ground moving target indicator* [GMTI]). Moreover, the capability and efficiency of an SBR/GMTI would necessitate an entirely new concept of operations. But there is good news here: to demonstrate the potential of such a system, DARPA has teamed with

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the Air Force and NRO on the *Discoverer II*. This technology demonstration will fly two prototype spacecraft by 2003, paving the way for the development and deployment of a constellation of 24–48 satellites by 2010. The program seeks to employ commercial-design practices to produce operation satellites at costs of $100 million per unit.

As for weapons, the Air Force has always been bedeviled by concerns over making space a battleground. Consequently, the Air Force—and the Army, for that matter—has had a number of unsuccessful antisatellite (ASAT) programs. I anticipate two reasons that would stimulate a wider debate on ASAT. First is the phenomenon that serves as the subject of this article—the commercialization of space. As more capability moves to space and as we become critically dependent upon that space infrastructure for our day-to-day living (much less our defense), I think the nation will want to provide the necessary protection and deterrence to attack. Here, the naval analogy of freedom of the seas is apt. The second reason is that the proliferation of high-resolution, remote-sensing systems presents opportunities for our adversaries to target our forces and facilities from space. I think our commanders in the field would want a system to negate the threat posed by this targeting capability.

As for permanently based weapons in space, for the mainstream body politic, this subject has always been politically incorrect. Frankly, I think that this will gradually change. More and more decision makers see

the need for a national missile-defense system, and the most effective and efficient way to defend the United States from missile attack would utilize a space-based system. The Air Force is also working with the Ballistic Missile Defense Organization to conduct a treaty-compliant space-based laser demonstration by 2008. Despite differences of opinion as to the correct technical solution, the maturity of the technology, and a plausible date for launch, we have discourse. The country must invest in these enabling technologies to ensure that we are ready when the need arises and the political will becomes manifest.

People have recognized space as a primary enabler for the revolution in military affairs. The Air Force, therefore, envisions that space will become even more important in the twenty-first century. As such, the military must take advantage of the tremendous capabilities now being developed by the commercial space industry. It is also clear to me that new space missions will emerge and that certain terrestrially based functions will move to space. To afford these initiatives, the Air Force must become more efficient in its space stewardship and sustainment. This requires another revolution—a revolution in business affairs. Commercializing selected space functions and adopting processes and practices from space's business world offer enormous opportunities for efficiency. □

Notes

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